Control Requirements and Field Experience with Mechanized Level Basins

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ABSTRACT

MECHANIZED irrigation systems provide a convenient means of applying the exact amount of water desired. Control is the key to successful on-farm use of mechanized gates. This manuscript discusses controller and control requirements for the mechanization of level basins, how the requirements were met, various successes and failures associated with the use of eight mechanized level-basin systems operated over the past 10 years, and many human aspects of using these mechanized systems.

INTRODUCTION

When drip/trickle and sprinkle irrigation are used, a predetermined quantity or depth of water can be applied to an irrigated area. Level basins can also be irrigated with predetermined volumes of water. Applying a predetermined volume of water is difficult, if not impossible, with other surface systems. Time-based delivery to level basins (either manually or automatically controlled) is satisfactory where the water supply rate is constant. In many agricultural irrigation systems, water is supplied from open channels where the delivery flow rate fluctuates considerable and time-based control of water deliveries may be unsatisfactory.

Mechanizing the on-farm gates of a level-basin irrigation system can assure accurate water application, provide labor savings, and provide a special convenience to the surface irrigator. Accurate water application can lead to both water savings and yield increases. Level basins generally involve a larger number of watering sets than sloping borders or furrows, e.g. the unit flow rate is higher with level than sloped, hence the area covered per set with a given flow is less. Thus, more frequent irrigation set changes are needed. Mechanizing to accommodate these relatively frequent irrigation set changes can be beneficial. The convenience or utility of mechanically opening and closing irrigation gates to direct water to level basins provides similar advantages for this type surface system that mobile machines have provided for sprinkle irrigation. Essentially all of the drudgery of irrigating is removed when level basins are combined with gate mechanization.

Traditionally, controllers used in the irrigation industry have been developed for turf applications where standard time-based control is satisfactory. A few commercial controllers are now available that provide control with either time or flow-rate bases. Control of the water supply for most turf irrigation applications is possible; e.g. pumps, master valves, etc. However, in most situations where water is supplied via open channels from Irrigation Districts, the on-farm water user does not have control of the farm delivery gate. Without control of the delivery point, on-farm mechanization requirements must include control features to handle water excesses.

Haise et al. (1981) reported research and development efforts associated with automation of surface irrigation over a 15-year period by the USDA at Ft. Collins, CO. Various aspects of automated control and controllers were described. Duke et al. (1982) reported on the development and use of a digital electronic controller developed specifically for surface irrigation that was capable of integrating flow rates from an open channel flow measuring device. Kidwell (1983) described a prototype automated system developed specifically to operate flood irrigation gates either on a flow-rate base or time base. The system featured a personal computer and radio telemetry for communication between the computer and the gates.

Mechanized or automatic control, as used in this paper, refers to the opening and closing of on-farm gates to effect successive irrigations of level basins on a farm. Irrigation changes are made according to predetermined schedules. Neither the control of the irrigation district delivery gate nor the irrigation startup signaled by the soil water or plant status in the field are included.

The ideas presented in this paper are the result of over 10 years experience associated with the design, installation, and maintenance of the eight mechanized systems used on farms in the Wellton-Mohawk Irrigation and Drainage District in Southwestern Arizona. The objectives are to discuss: (a) pertinent controller and control center requirements that are needed when the water supply is not under the direct control of the farm operator, (b) how the requirements were met for eight mechanized level-basin systems, and (c) field experiences, especially the various human aspects, associated with using these mechanized systems.

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BACKGROUND

Eight operational mechanized level-basin systems were designed, installed, and operated in the Wellton-Mohawk Irrigation and Drainage District since 1975. The first two systems were installed by the USDA-Agricultural Research Service. The last six were completed as part of an on-farm irrigation improvement program administered by the Soil Conservation Service. All were constructed as part of a program to reduce irrigation return flows from the Wellton-Mohawk in support of Title I of the Colorado River Basin Salinity Control Act (Public Law 93-320). The fields that were mechanized ranged from 26 ha (64 acres) with 23 basins to 94 ha (231 acres) with 18 basins (Table 1). Lift gates were actuated with pneumatic cylinders (Dedrick and Erie, 1978) while port closures were effected using air pillows (Erie and Dedrick, 1978).

The controls for all mechanized level-basin systems were located within or adjacent to the field. Control was based on the premise of applying a predetermined volume of water to a basin to accomplish an irrigation. The communication links between the controller and the basin gate were either hardwired electrical signaling or small-tube pneumatic signaling similar to many golf course layouts.

HUMAN ASPECTS

The type of labor or manual activities associated with level-basin irrigation is considerably different from that associated with most surface systems in that little hand/shovel work is required (Dedrick, 1984). The fact that little hand labor is needed enhances the possibility that the irrigation will be done properly. Hence, it is potentially feasible to manually irrigate level basins just as efficiently as when mechanized, but a number of roadblocks prevent getting the job done properly. The main problem is making the prescribed gate changes at the precise time. Delayed gate changes lead to over-application of water which becomes more serious as the supply flow rate increases and/or the basin size decreases. For example, closing a gate 2 min late on the MM#1 system (Table 1) results in an over-application of about 9 %. Conversely, a 2 min delay in gate changes on the larger basins of some other farms shown in Table 1 would be insignificant (about 1 %).

The irrigation psychology between a farmer and his irrigator can also play an important role in whether correct amounts of water are applied. The general tendency is for the irrigator to over-apply, since such an action may not be detectable by the farmer, while an under-application may be. This psychological constraint can likely be removed if the farmer provides an irrigation guide for the irrigator, e.g. irrigation set time guide for each basin related to flow rate. This same irrigation guide would be used by the grower to program a controller.

CONTROL REQUIREMENTS

Several "MUSTS" are associated with any control system in the irrigation industry. These "MUSTS" include (a) must be reliable, (b) must be cost effective, and (c) must be user friendly. Controller functional requirements, especially those pertinent to level basins, have been developed. Although most of these requirements apply to controllers for surface irrigation in

TABLE 1. MECHANIZED LEVEL-BASIN IRRIGATION SYSTEMS IN THE WELLTON-MOHAWK IRRIGATION AND DRAINAGE DISTRICT.

Year Installed	Farm	Field area, ha (acres)	Number of basins	Irrigation completed by farmer or separate irrigator	Controller history
1975*	WH	26 (65)	8	Generally separate irrigator	Originally electrical/mechanical to provide pneumatic signal to gates. Converted to AC-powered electronic control in 1981. Discontinued use in 1984.
1975*	NQ†	28 (70)	8	Irrigator	Same as above.
1977	MM#1	26 (64)	23	Farmer	Originally electrical/mechanical to provide pneumatic signal to gates. Converted to AC-powered electronic control in 1982. Converted back to electrical/mechanical control (original system) in 1985.
1979	JH#1	44 (110)	8	Irrigator	Originally portable DC-powered, electronic controller to provide electrical signal to gates. Replaced with AC-powered electronic controller in 1982.
1979	HE#1	32 (80)	12	Irrigator	Same as JH#1, above.
1980	MM#2	31 (76)	9	Farmer	AC-powered electronic controller to provide electrical signal to gates. First system installed to provide flow-rate based (volumetric) control to the basins.
1985	HE#3	94 (231)	18	Irrigator	Electrical/mechanical to provide electrical signal to gates.
1986	HE#4	68 (169)	16	Irrigator	Same as HE#3, above.

*Research and demonstration at USDA-ARS request, all others were operational systems completed as part of an on-farm irrigation improvement program administered by the Soil Conservation Service.
†Mechanized ports—all other systems were lift-gates.

general, they do not include specific requirements of some techniques such as surge irrigation. The early work reported by Haise et al. (1981), dealing with the automation of surface irrigation systems, played an important part in the development of these requirements. Many of the ideas were discussed at a USDA-Agricultural Research Service meeting in Ft. Collins, CO in 1975.

The capability of signaling gate or valve changes is basic to any controller, but many other considerations are required to enable the operator to be in full command of the irrigation. Some constraints are related to the on-farm handling of the water and others related to the fact that the irrigator may not have direct control of the irrigation water supply (delivery from an Irrigation District).

General Surface Irrigation Controller Requirements

The following list presents some of the controller requirements specific to surface irrigation.

1. Individual time or volume settings should be possible for each station controlled in any one irrigation cycle.
2. All stations (sets, basins, etc.) should be controllable in any random sequence selected by the user.
3. Programmed time or volume setting and sequence should be maintained from irrigation to irrigation.
4. Controllers must be adjustable to within 2 or 3 % of the irrigation time setting or water volume required. Set-time of at least 9 or 10 h per station is required.
5. Volume-based controllers should be capable of operating with sensing from a remote flow sensor.
6. The controller monitoring system should be capable of providing a current status report including the station being irrigated (signal being sent), time or volume yet to be applied, and the current gate status (e.g. open or closed). The display must be readable in direct sunlight.
7. The operator must be able to manually advance the controller to any station without interfering with the automatic operation of the controller.
8. The operator must be able to manually restart the irrigation sequence regardless of the current station status.
9. The controller needs to be capable of advancing to the first station when a remote signal is received.
10. The controller system must be able to accept remote signals in response to various system malfunctions and be capable of alerting the operator.
11. The contoller system must be capable of disposing of excess water either remaining in or continuing to be fed into the on-farm canal after the irrigation sequence has been completed.
12. The system must be either battery operated or have battery back-up if AC-powered. The controller must be protected against power surges, especially those caused by lightning. Batteries must either be automatically recharged from an AC power supply or from an onboard solar charger. Momentarily-energized, rather than continuously-energized, solenoid valves should be used to conserve the power supply of battery operated contollers.
13. The signaling requirements depend on the communication linkage used.
14. The enclosure must be sufficiently dustproof and raintight to protect components from an outdoor environment. Components must be able to function at ambient air temperatures as high as 50 °C.

DISCUSSION OF CONTROL REQUIREMENTS—FIELD EXPERIENCE

Controller Evolution in the Wellton-Mohawk

The type of controllers used has changed somewhat over the years, finally with a reversion back to the type first used during the early research and development stages (Table 1). Electrical/mechanical controllers were first used by Haise et al. (1981) on a farm in Mesa, AZ in the late 1960s. Electrical/mechanical controllers were also used to sequence water from basin to basin (Dedrick and Erie, 1978; Erie and Dedrick, 1978; and Dedrick and Zimbelman, 1981) for the first three farms in Table 1. These AC-powered controllers proved to be both reliable and easy to operate. The MM #1 system was operated for about 100 irrigations without controller malfunction from 1977 through 1980. This would suggest that the electrical/mechanical controllers are relatively unaffected by problems associated with the AC power supply, e.g. lightning or other power surge problems.

Electronic-based (digital) controllers used in the turf industry were interfaced to electronic head detection equipment at primary open-channel flow measuring devices (Functional Requirement #5) in an effort to overcome flow delivery fluctuation problems both during an irrigation and from irrigation to irrigation. This interfacing provided volumetric control of the water delivered (Dedrick and Pettit, 1983). The electronic controllers also provided exact time settings for each station in 0.1 h increments up to 9.9 h or 1 min increments up to 99 min (Functional Requirements #4) and provided a continual status report of the station being irrigated along with a display of time remaining on that station (Functional Requirement #6). Although this system was inexpensive and simple (Dedrick and Pettit, 1983), problems attributable to lightning damage, power outages or brownouts, and/or programmer error became apparent during 1984. These ranged from outright controller failure to loss of programmed times. Each failure resulted in a system shutdown and required maintenance.

Lightning and power outages: The failures were usually in the controller, indicating a power surge on the 115 VAC incoming power line. Components in the DC power supplies to the field or the head detection equipment also failed in several instances. This suggested an induced power surge from the DC signal lines caused by a lightning strike near the gates or the control center. Low cost surge protection devices were successfully used on several of the systems where electronic controllers were used. Replacement of the surge devices after a failure is, however, an inconvenience to the user and interferes with the day-to-day use of the system.

Lightning strike feedback from gates to the control center can be eliminated by using pneumatic or hydraulic signals to the gates. Pneumatic signaling was originally used on the first three systems shown in Table 1.

When electrical/mechanical controllers were used, resumption of an irrigation is generally assured after an AC power outage, since the station or position they were in when the power outage occurred is maintained mechanically. With controllers which provide pneumatic signals (which are pneumatically backed-up), once the power is restored, the controller continues from where it left off. Short term power outages undoubtedly occurred during the period that the electrical/mechanical system (MM#1) operated during the late 1970s without reported incident. Excess water would have been applied during these power outages with the excesses proportional to the time the controller was off. The amount of excess water applied would have been small (power off only a few minutes). Chances are the irrigator or farmer would not have been aware that a power outage occurred.

Generally electrical/mechanical controllers were easier to use than electronic controllers since each station is represented by an individual dial. Once set, the program time cannot be lost be power failure since the dial is a mechanical device. At least one commercially available electronic based controller uses mechanical thumbwheels for setting each station individually.

The original electrical/mechanical controller was reinstalled on the MM#1 system in 1985, Table 1, in an effort to regain system reliability and more importantly to simplify programming for the user. In addition, two mechanized level-basin systems were designed in 1985 with electrical/mechanical rather than electronic controllers, again to assure ease of operation and reliability.

Programmer Error: Numerous user problems with the operation of the electronic controllers occurred from 1980 through 1984. Most were attributable to the user not fully understanding how the programming should be done, few of the programming steps were self explanatory, and successful use of the controllers required extensive study of the users manual. Several other items contributed to these problems and include: (a) certain functions on the controllers specifically related to the turf industry, such as time-of-day and day-of-week startup options, created confusion for the programmer since they were not needed in this case; (b) many times the programmer (irrigator) did not have command of the English language and in some instances probably felt threatened by mechanization; and (c) confusion exists on the part of the operator as to how to make changes in a program while irrigating. The last point is especially crucial since the on-farm canal system can be damaged if a gate were inadvertently closed. This would not be a concern if the operator and controller had direct control of the water supply from the Irrigation District.

An extra (practice) controller, equipped with indicator lights on the output stations, was available to help train or familiarize the users with the controller. The practice controller and lights were provided as a single, portable unit that could be conveniently used at any time or place. To simplify the controller use only those programming and operational steps needed by the user were excerpted from the users manual, the explanation was simplified where possible, and these were then posted in the control center enclosure for easy reference.

Meeting Controller Requirements in the Wellton-Mohawk

The following is a description of how the various control requirements, listed previously, were met for the level-basin systems mechanized in the Wellton-Mohawk. In certain instances the requirements were satisfied by using peripheral equipment external to the controllers.

Individual time or volume settings for each station: The stations of all controllers used could be individually set.

Basin sequence selection: Sequence selection was programmable with the DC-powered controller originally used on the JH#1 and HE#1 systems. Sequence selection was not programmable with either of the other two controllers used—controllers advance from one station position to the next until all stations have been activated. Selection panels were used to provide random sequencing (Dedrick and Zimbelman, 1981). Selectivity with pneumatic signals was achieved by connecting the air tubes used to signal the gates to the appropriate controller output tubes, in whatever sequence desired, by means of flexible tubes and quick disconnects (Dedrick and Erie, 1978; and Erie and Dedrick, 1978). With electrical signals, output channels from the controller were simply connected to the desired basin signal lines by proper placement of a contact pin on the selection panel (matrix board).

Random sequence selection may not be necessary on many farms and tends to complicate the use of the system. In a few instances mistakes when setting the selection panels led to irrigation errors. When the original electrical/mechanical controller was reinstalled on the MM#1 system in 1985 the farmer decided to eliminate the sequence selectivity function that was part of the system when installed in 1977. They found that a single sequence for irrigating the 23 basins was satisfactory and simplified their operation.

Maintenance of programmed time and sequence from irrigation to irrigation: Time settings are inherently maintained with the electrical/mechanical controllers. The programmed time with the AC-powered electronic controller had battery back-up and generally worked properly during power outages of 1 h or less. Programmed times were not maintained in all instances and were linked to AC power line surges and/or lightning.

Controller station accuracy and precision (time base): Time settings with the electronic controllers are highly precise (digital). This was one of the underlying reasons for switching from electrical/mechanical to electronic controllers, especially when irrigation time settings are short, as explained earlier for the MM#1 system. Each station time on the electrical/mechanical controller is adjusted by an individual station timing knob (continuously adjustable). The resultant accuracy is dependent on the calibration or adjustment of the knob and the ability of the user to set the knob properly. The average standard deviation of 17 stations repeating a 1.25 h setting from irrigation to irrigation (station knobs not reset) was about 2.8 min for the controllers used on HE#3 and HE#4 (Table 1). These controllers were equipped with 9 hour timers. Initial station timing knob calibration (the accuracy with which the controller reproduces the time setting indicated) requires four or five repetitions in adjusting and testing. The ability of a user to set a station timer and repeat the results of previous runs was tested by having three persons set a controller independently three different times. After each setting the controller was allowed to run through its cycle. Time was recorded for each controller station. Again 17 stations were used. Interestingly, the variation from setting to setting for the three operators was nearly the same as or less than when the knobs were not reset (average standard deviations were 3.2, 1.7, and 1.7 min for the three operators). Only on the small basins would such variations be a problem. The repeatability is acceptable for the larger basins where average time settings would be 2 h or more.

Operation on volumetric basis from a remote flow sensor: The volume of water delivered may be controlled by either integrating the flow rate delivered with time (Duke et al., 1982) or adjusting (shortening or lengthening) the controller's programmed delivery time, based on flow rate differences from a preselected nominal flow. The second alternative was developed for farms WH, NQ, JH#1, HE#1, and MM#2 (Table 1). The procedure required that a frequency be provided to the controller clock that was proportional to flow rate measured at a primary open-channel measuring device (Dedrick and Pettit, 1983). Changes in frequency output were translated into exact controller time changes.

Controller station accuracy (volumetric): Even though the frequency to time conversion was exact, the overall accuracy of the system is dependent on how accurately the water head at the primary measuring device can be detected and how accurately this head, represented by an electronic signal, can be electronically translated into a frequency proportional to flow rate. Dedrick and Pettit (1983) found that the error in electronic translation from head to flow rate of some commercially available electronic equipment (an excitation/amplifier, a power function amplifier to relate head to flow rate, and a voltage controlled oscillator) was 1 % or less over a broad range of flows for a measuring device typical of those used in the Wellton-Mohawk.

Primary open channel measuring devices are available with flow rate accuracies of $\pm$ 2 % to $\pm$ 3 % (Replogle, 1978). To maintain a $\pm$ 2 % accuracy for a typical broad-crested-weir used in the area, the head detection must be within $\pm$ 3 mm ($\pm$ 0.01 ft) for flow rates of about 0.4 m^3/s (14 ft^3/s) or less. Few available head detection devices can meet this detection accuracy over extended periods of time and under the adverse environmental conditions encountered in irrigated agriculture without continual attention and re-calibration (Clemmens and Dedrick, 1984). Pressure transducers coupled with bubblers were used to detect the head from flumes or weirs on the WH, NQ, JH#1, and HE#1 systems starting in 1981. Transducer output was satisfactorily stabilized (Dedrick and Allen, 1981) by elevating and maintaining the temperature around the transducers above ambient.

Current status of irrigation: The time remaining to complete an irrigation and the station being irrigated (signaled only) were standard status functions provided by the electronic controllers. Irrigation status was provided for the systems installed in 1985 and 1986 (Table 1), which utilized the electrical/mechanical controllers, by indicator lights on a display panel set up in a schematic layout of the basins. Two lights per basin were used, the first indicating which basin was being signaled and the second indicating whether or not the gate was open. The second light was powered by an electrical feedback system from the basin gates to the display panel. The feedback powered the indicator light and controlled a digital clock providing the operator with the current lapsed time that a basin had been irrigating. These features were also useful when checking the system at night or for completing a quick checkout before an irrigation starts.

Manual operation: All controllers used in the Wellton-Mohawk project allowed operator-manual-control to either advance the controller to the first station, to advance the controller to subsequent stations, or to restart the irrigation sequence regardless of the current status of the controller. On the systems where selection panels (matrix boards) were used, a MANUAL matrix row was included, which allowed the gates to be operated manually without use of the controller. Such manual operation would be used in case of a controller malfunction. This function allows the irrigator to irrigate without physically going to the gates to effect an irrigation change and avoids having to reconnect gates for total manual operation.

Remote start: The controllers used were either equipped to automatically advance to the first programmed station when remotely signalled, or were modified to achieve this function. In all instances, a switch closure was required. The remote signal was provided by a float switch located along the canal which is normally used to provide a signal if the canal water level exceeds a safe level (Dedrick and Erie, 1978; and Erie and Dedrick, 1978).

Disposal of excess water: None of the controllers was capable of disposing of water in excess of that expected, either excessive water level (depth) or flow after the last basin was irrigated. Increased depth could be caused by a gate not opening when signaled or only partially opening. Excess water depth was controlled independently of the controller. Excess water depth is sensed with the float switches mentioned in the previous section. Signals from the float switches are sent to designated gates to cause gate openings regardless of the status of the irrigation event. Once the water level drops, the overflow signal is canceled and all gates return to the pre-overflow condition. The cycle is repeated indefinitely until either the overflow corrects itself or the cause of the overflow is determined and corrected by the operator. If desired, signals from the float switches can be used to provide a system malfunction alert. A light, mounted outside the control center of the MM#2 system, was used as such an indicator.

Continued water delivery to the farm after the last basin has been irrigated may occur if the on-farm irrigator does not have control of the water delivery. Further, it may be desirable to empty the on-farm canals once the irrigation is completed. Excess water delivered from an Irrigation District and on-farm canal drainage after the irrigation is complete were handled by directing the water into designated basins with the use of an additional controller station to open the gates. The gate selection can either be hardwired or can be selectable by the irrigator with the use of an additional row on the matrix board. This RUNDOWN row on the matrix board is powered by the extra controller station. The underlying assumption is that the amount of water diverted after shutdown will not continue indefinitely and create additional problems for the operator.

Disposal of water in case of power failure: Since control of the water supply from an Irrigation District is not possible at the present time, incoming water must be controlled on-farm in case of power failure. This is done by routing the incoming water to a designated basin or basins with normally open gates. In this project helical springs are added to the designated gates to achieve the normally open mode when the compressed air was lost.

SUMMARY

Eight operational level-basin systems have been mechanized in the Wellton-Mohawk Irrigation and Drainage District since 1975. The USDA-Agricultural Research Service designed, installed, and maintained the first two systems for research and development purposes. The other six systems were completed as part of an on-farm irrigation improvement program administered by the Soil Conservation Service. The latter six systems were owned and operated by individual farmers, but were also used for further research, development, and evaluation.

A listing of "optimal" controller or control center functional requirements for level-basin mechanization is presented. The evolution of this equipment in the Wellton-Mohawk has helped identify and evaluate the utility, practicality, and/or necessity of the various requirements. For example, the reasons to switch from electrical/mechanical to electronic controllers were founded on: (a) need for volumetric control to the basins, (b) ability to set the time-or volume-of-application precisely, and (c) provide a continual status indication of which station was being irrigated and the time remaining. However, problems due to lightning damage, power outages, power surges, and programmer error (user problems) negated some of these potential advantages. In three instances in the Wellton-Mohawk, the users have opted for more simplistic electrical/mechanical controllers for reliability and "user friendliness".

CONCLUSIONS

Several general conclusions associated with controls for mechanized level-basin systems are apparent from the years of experience in the Wellton-Mohawk.

Generally, control centers equipped with electrical/mechanical controllers have been more reliable and easier to use than those equipped with AC-powered electronic controllers. At the same time, electrical/mechanical controllers do not provide the flexibility and accuracy that most electronic controllers can furnish. Lightning related problems can be reduced with proper surge protection equipment, but power fluctuation may be disruptive to proper field operation of the electronic controllers. Completely DC-powered control coupled with hydraulic or pneumatic signaling would eliminate most of the problems associated with the AC power supply, although inherent problems associated with maintaining and conserving the battery system would require attention. A few controllers are now commercially available which operate on these principles.

Inherently, open channel flow delivery is more complicated to manage than is a closed system. Lack of complete control by the operator leads to the need for the system to be highly reliable. Fail safe features must be built into the system in order to manage the incoming water in the event of any number of possible control failures.

Generally a mechanized system becomes more complicated as more user flexibility is built into the control centers. These complicating factors occur both from a user standpoint and from a maintenance standpoint. Examples of flexibility include random sequence selection, volumetric control, status of an irrigation, and selection of gates used to dispose of excess water. Selectivity may not be necessary for some farms and generally should be kept to a minimum. Operational utility of the system, however, should not be undermined. For example, if delivery flow rates vary widely during an irrigation and/or from irrigation to irrigation, then volumetric control is essential.

The use of turf oriented controllers in the agricultural field tends to complicate the use of the controller since a number of functions used in turf applications are not applicable to agriculture. Successful use of electronic controllers generally requires extensive study of the user manual and experience in the use of the system. If the system is not easily used without requiring extensive study, then the system likely will not be used. Communication between the farmer and the irrigator may be a problem, especially if the irrigator does not have command of the English language.

The overall accuracy of a flow-rate-responsive controller for open channel flow is dependent on how accurately the water head at a primary measuring device can be detected. Generally head detection techniques do not meet the accuracy requirements ($\pm$ 2 % to 3 %) without becoming exceedingly expensive.

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